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Experimental analysis of ex-vessel core catcher cooling system performance for EU-APR1400 during severe accident

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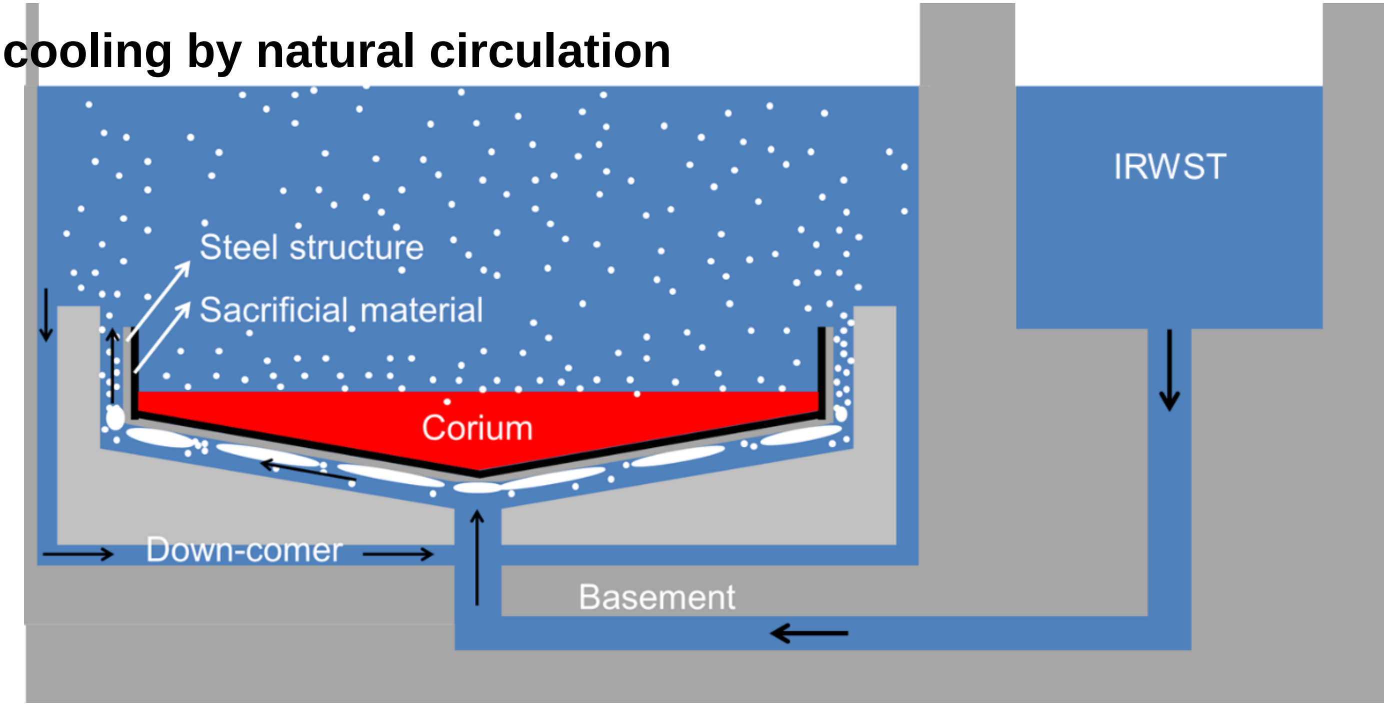
Introduction (1/3)

External cooling by natural circulation

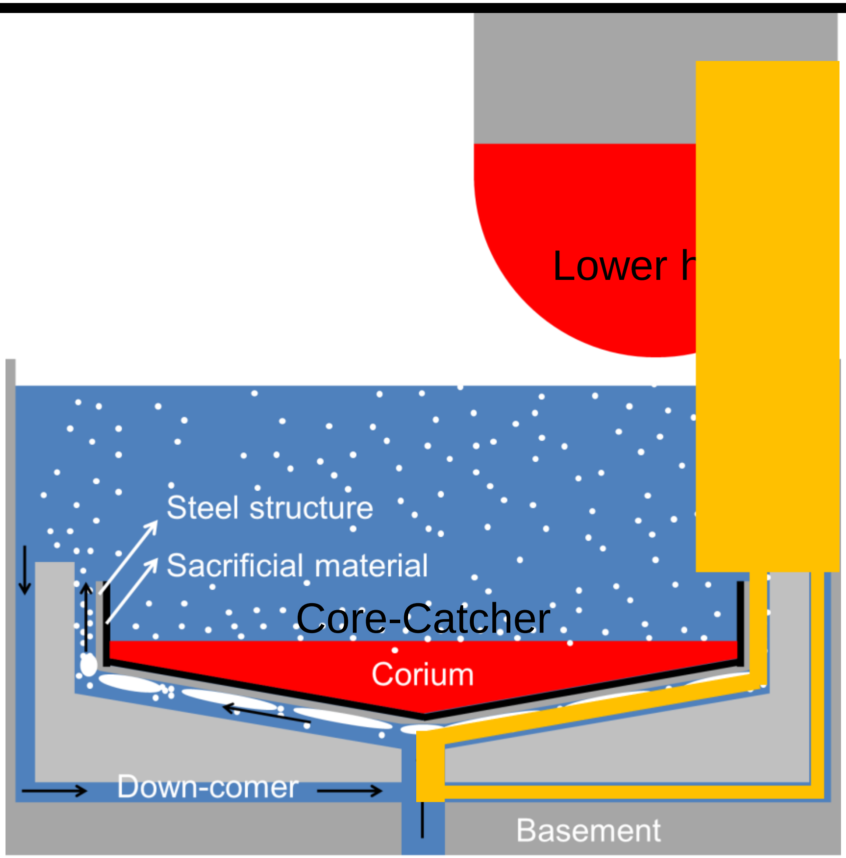


✓ Natural circulation cooling is a reliable method to **passively** **remove** decay heat and **prevent corium** from escaping the containment building.

✓ Total amount of steam generated should remove the decay heat. "**natural circulation flow rate** in considered heat flux"

✓ Film boiling and/or local dry out should be avoided under expected heat flux level. **"To know CHF level for the specific geometry"**

Introduction (2/3)



Level of CHF for considered geometry under natural convection?

Results of small scale experiments are not suitable to extrapolate to large scale structures.

∴ Large scale experiments

- CYBL
- ULPU
- SULTAN
- SBLB

"Capable of cooling for specific reactors"

"CHF larger than $1 MW/m^2$ under natural circulation"

"Void fraction, temperature, CHF, h"

+ CE-PECS

- Full scale in height and width of core catcher
- Half of symmetric geometry
- 30 cm slice of coolant channel -> scaling

Introduction (3/3)

To evaluate heat removal capability of core catcher system

Experimental Scope

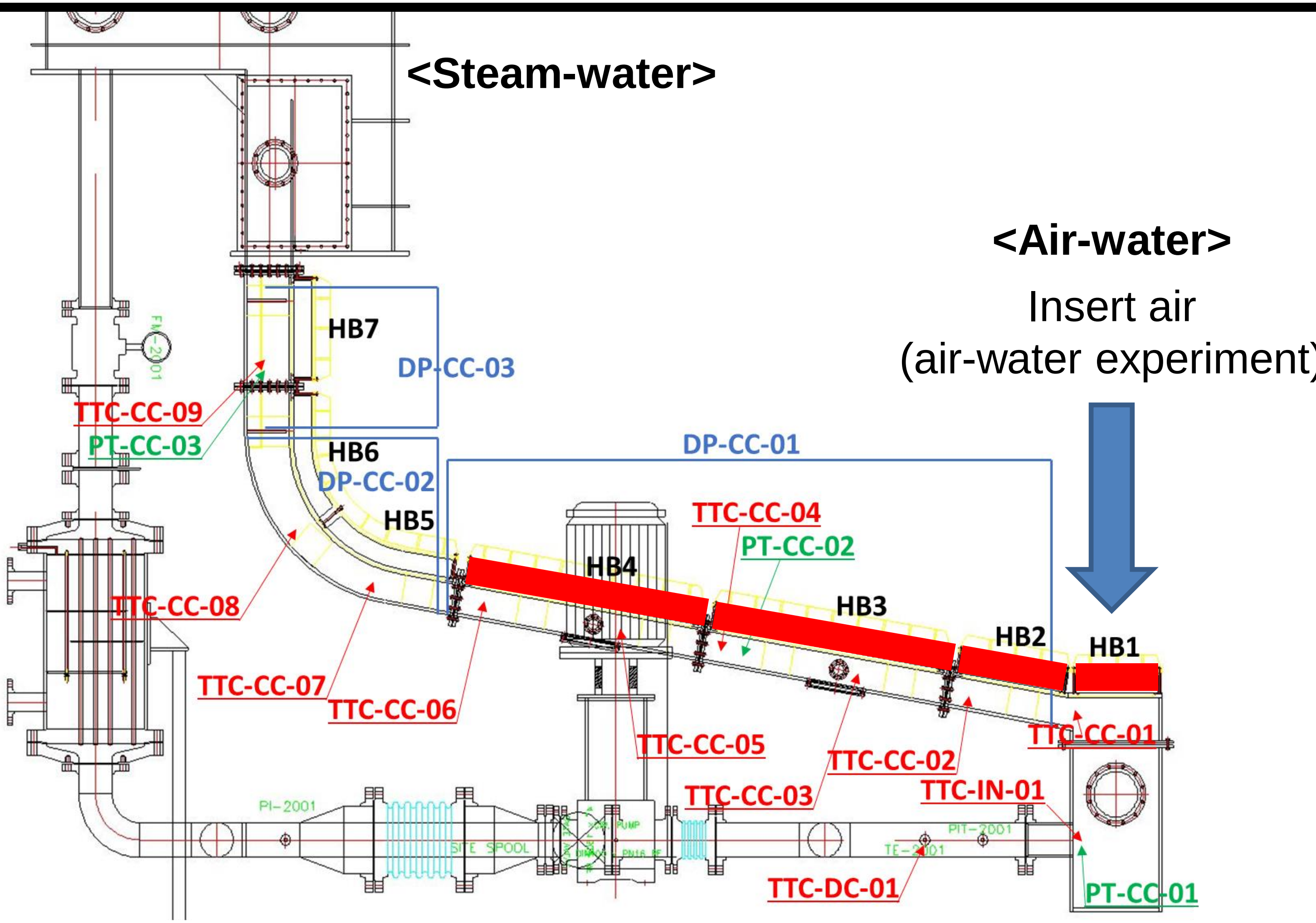
1. Natural circulation flow rate measurement under specific heat load and compare with the result of air-water experimental case.

2. Observation of wall temperature and local heat transfer coefficient distribution on the downward facing heater block.

3. Analysis of heat exchange mechanism at specific geometry by visualization and probe measurement.

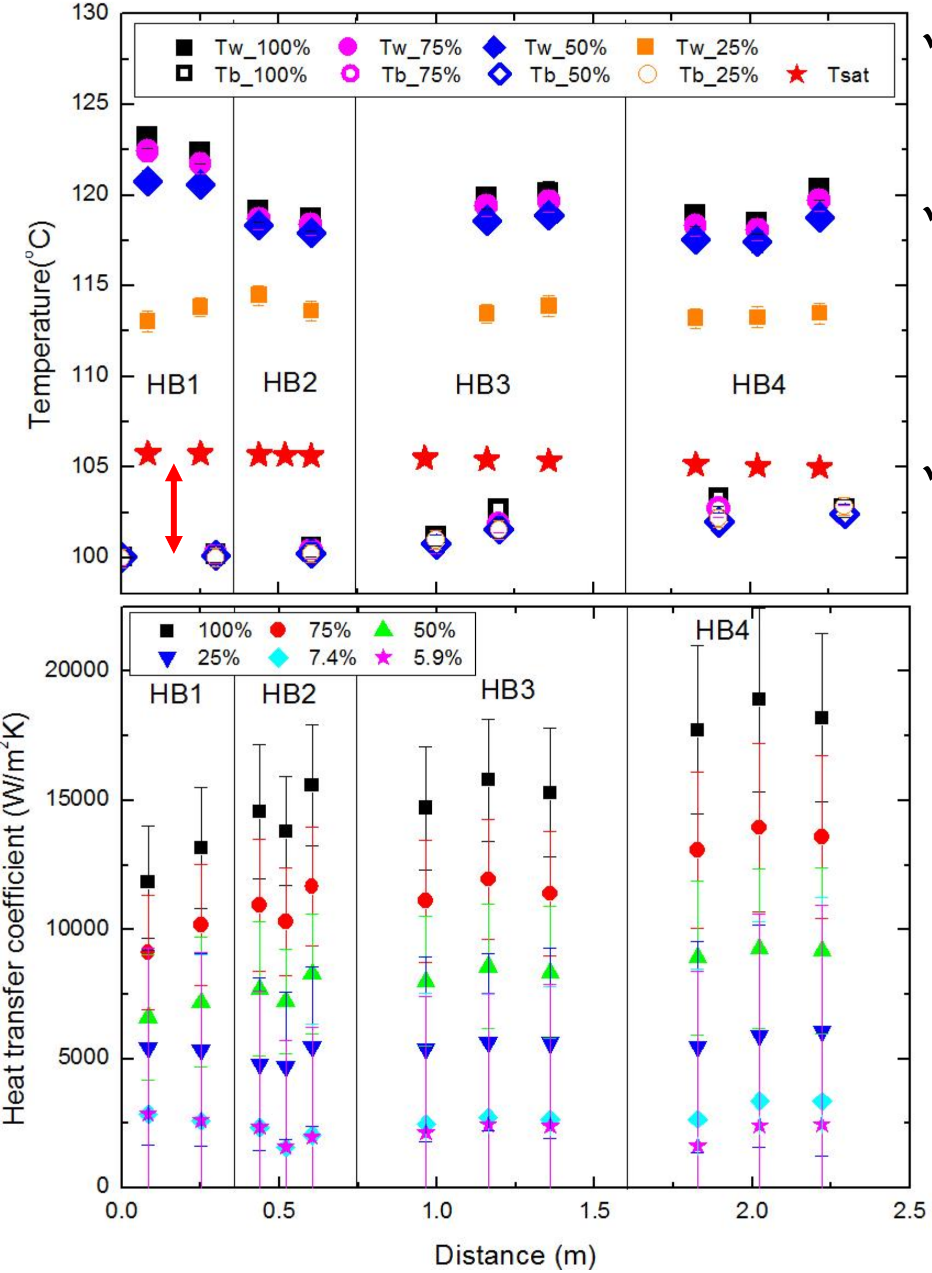
4. Test whether CHF occurs under severe accident simulating condition.

Experimental Facility (1/1)



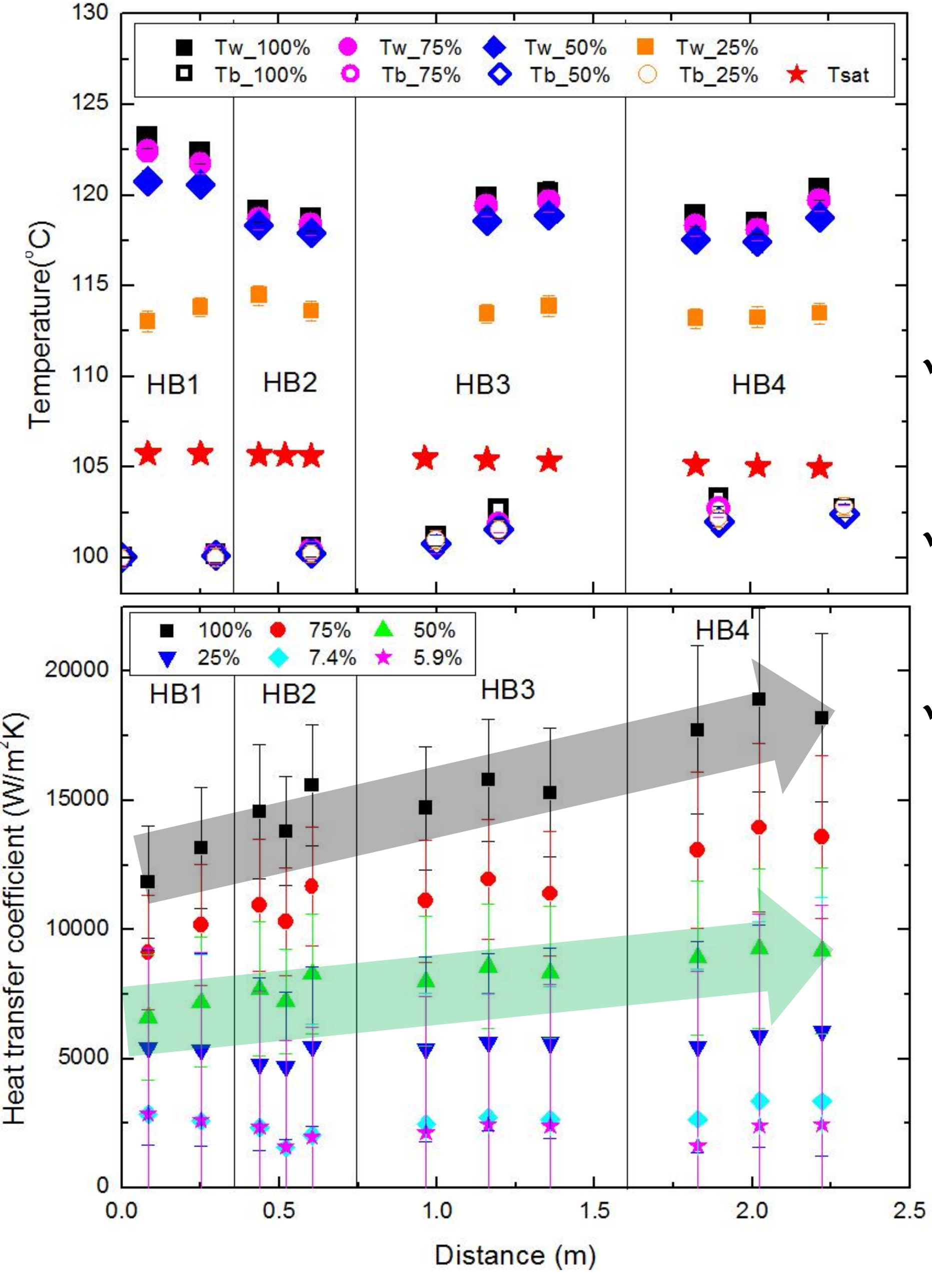
Total Heat [kW]	q'' Distribution [kW/m^2]	Mass Flow Rate [kg/s]	Water Level [m]	Pipe dia. [mm]	State
48 – **190**	75 - **299**	Natural circulation	3	100	Steady

Results (1/5)



- ✓ High T_w & Low heat transfer coefficient at HB1 => Stagnation at 180° curve
- ✓ Due to the static pressure difference between down-comer inlet and outlet, inlet water is subcooled condition.
- ✓ Very active nucleate boiling occurs near the wall even the bulk temperature is subcooled condition. – **stratified flow**

Results (2/5)

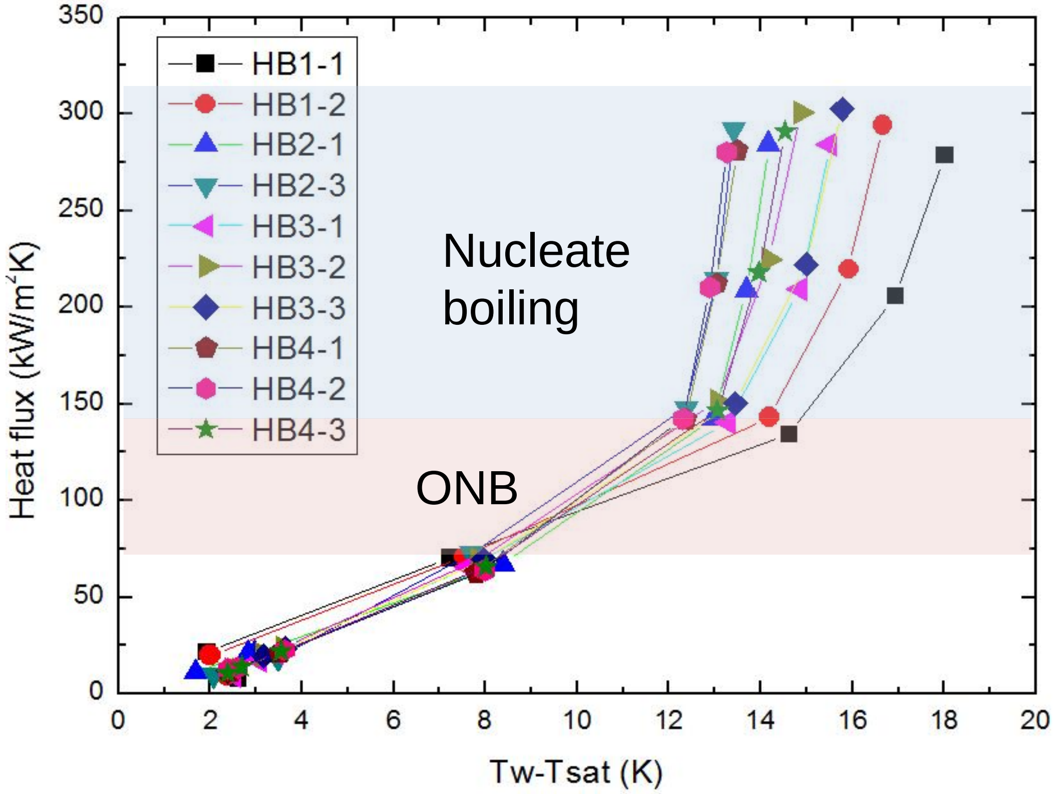


Heat transfer coefficient increases

toward downstream of the channel.

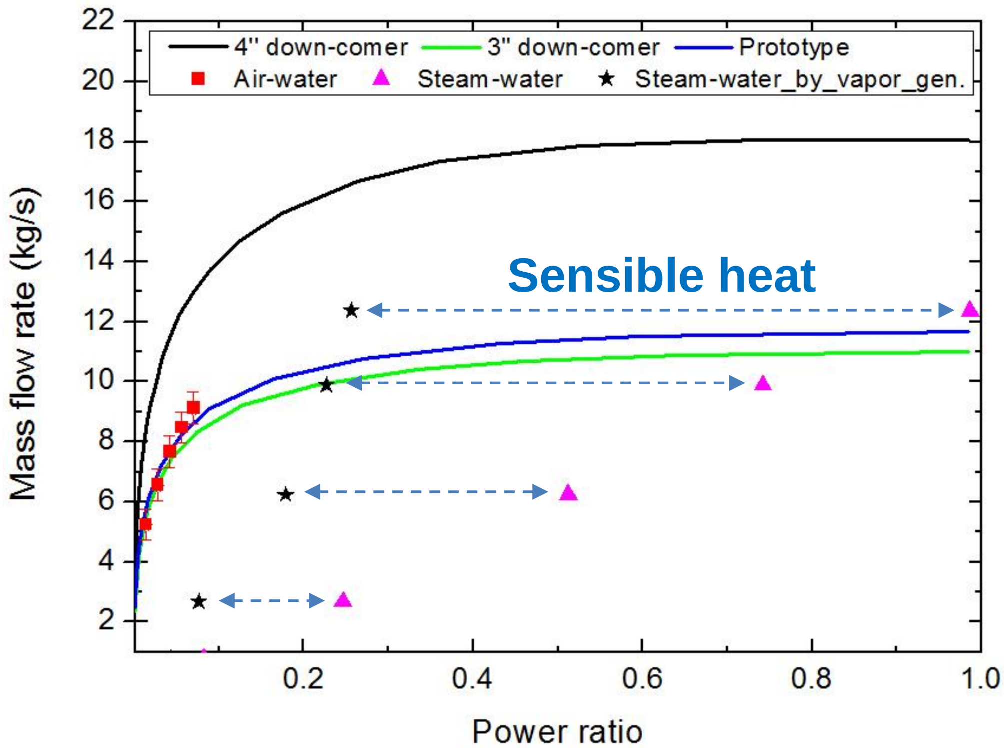
- ✓ Increase of bulk temperature generates vapor more actively: **Nucleation** ↑
- ✓ Liquid flows quicker when void fraction is higher: **Convection** ↑
- ✓ Bubbles are **accelerated** at the bend

Results (3/5)



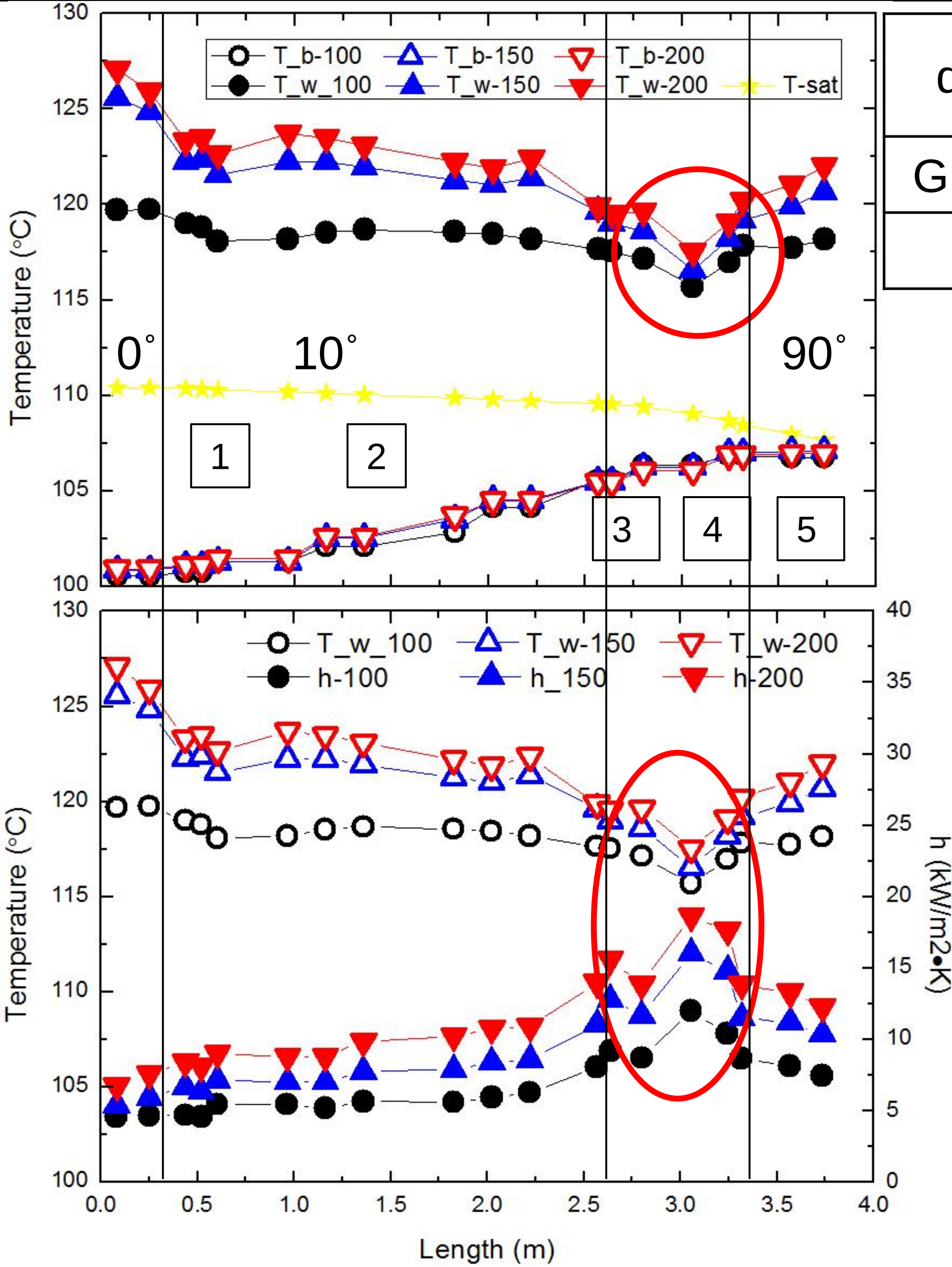
- ONB between 75 – 150 kW/m²
- 150-300 kW/m² : Nucleate boiling region
- <u>**CHF does not occur**</u> **under expected thermal load.** – Conservative condition to supply heat only on the downward-facing heater surface

Results (4/5)



- Steam-water experiment shows **lower flow rate** than air-water experiment and calculation result by homogeneous equilibrium model.
- In steam-water, generated **vapor condenses** to heat up the liquid temperature, so **buoyant force decreases**. With the exception of sensible heat, steam-water experiment shows similar inclination with air-water case. – minor loss difference
- Air-water experiment simulating steam-water system overestimates natural circulation flow rate -> Water head makes subcooled inlet temperature which makes **negative effect on natural circulation**.

Results (5/5)



q'' [kW/m²]	100	150	200
G [kg/m²sec]	70.4	120.7	154.4
x	0.00884	0.00696	0.00769

flow regime transition

Low T_w & **High heat exchange** at bend

Conclusions (1/1)

1. Coolability test for core-catcher cooling channel is carried out in conservative thermal load condition – downward-facing channel only.

2. Wall temperature and local heat transfer coefficient distribution along the channel is obtained which is **able to remove decay heat** **without CHF occurrence** under severe accident.

3. **Natural circulation flow rate** in various heat level is measured. Air-water experiment overestimates mass flow rate in natural circulating system due to channel inlet subcooling by hydraulic head difference.

4. **Low wall temperature and high heat exchange coefficient at the bend** due to **local acceleration and mixing** phenomena.

Thank you for listening!